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TIMBER PATHOLOGY IN RELATION TO WOOD UTILIZATION IN CANADA

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TIMBER PATHOLOGY IN RELATION TO WOOD UTILIZATION IN CANADA

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Timber Pathology in Relation to Wood Utilization in Canada

By C. W. Fritz, B.A., M.Sc., Ph.D.

I. *Introduction*

The decay of timber, both standing and structural, is due to the growth of fungi in the wood tissues. Fungi are plants. They, therefore, require food, air, moisture, and a certain range of temperature for their development. The fungi which grow in wood obtain their food from the wood tissues; air is present in all wood which is not saturated with water; and temperatures ranging from freezing point to above 100° F. and moisture contents from 15 per cent to almost complete saturation permit fungus growth. The food supply is, therefore, always at hand; and the air, temperature, and moisture conditions for growth are likely to be present at some season of the year in most situations in which wood is used. In order to prevent decay, therefore, environmental conditions must be regulated in such a way that one or more of the factors which govern fungus growth is controlled.

To most people the growth of punks, conchs, or toadstools on tree, lumber pile, or cellar floor means little. Whence they come, how they grow, and what they signify are questions of but passing interest. And yet their development is of vital importance to the lumber industry, for their presence proclaims the maturity of plants which have grown within the wood, and which, at the expense of the wood substance, have thus developed to the fruiting stage. These fruiting bodies are often the first external evidence of decay, and appear only when the fungus plant has reached its final stage of development and after the interior of the woody substratum has been reduced to a worthless mass.

Since the proof of the fungous nature of timber disease was established more than fifty years ago, extensive and varied studies have been made of the fungi which cause decay, and of their development in woody tissues. In Canada, however, pathology is still in its infancy. As recently as 1915 the first Timber Pathologist was appointed by the Federal Government; in 1918 studies of forest tree diseases were initiated by the government of Ontario; in 1921 an officer was appointed by the federal Department of Agriculture to study forest pathological problems in the field. Investigations have also been carried on by members of the staffs of the botany departments in some of the universities, particularly at the University of Toronto and at the University of British Columbia; and experts have occasionally been engaged by wood-using industrial companies to investigate troublesome pathological problems arising in their manufacturing processes. The workers, however, have been few, and the field for study extensive; wherefore it will be seen that studies in timber and forest pathology in Canada are still in an early stage of development.

Timber pathology, as it has been carried on by the Forest Products Laboratories of Canada, embraces the pathology of wood *under service conditions*. It leaves to the attention of the forest pathologist the vast array of leaf and root diseases which affect the annual production of wood, the cambium diseases which weaken and eventually kill trees, and the wide field of pathological investigations, such as age-infection studies, which seek to furnish information to provide for the maintenance of healthy forests with sustained yield. Timber

Pathology, however, shares with forest pathology the field of timber rots initiated in the forest. It seeks information as to the geographical and host distribution of all such diseases, and aims to establish their etiology and manner of development; but, in addition, it carries on the study to a consideration of the reactions of these types of decay to service conditions, and aims thereby to establish a sound basis for the profitable utilization of diseased material, which is unfortunately all too abundant in the unregulated natural forests of Canada. Peculiar to timber pathology itself is the special field of wood diseases, which may be contracted under conditions of storage or service.

It is with Timber Pathology that this paper deals.

II. *Organization and Equipment*

Two officers are engaged in the Forest Products Laboratories of Canada at Ottawa to carry on the work in timber pathology, and one other is similarly employed in the laboratories at Vancouver.

The pathological laboratories in Ottawa include an office, general laboratory, laboratory for sterilizing equipment, and room for the storage of the growing collection of pathological specimens. The laboratories are well equipped with apparatus for general pathological work, and new equipment is being added as the need arises.

III. *Service Rendered*

The work of the division is included in three categories:—

A. Fundamental research;
B. Industrial research;
C. Technical service.

The problems confronting the division in *fundamental research* may be grouped in three classes: (1) diagnosis of wood rots; (2) chemistry of decay; (3) conditions favouring or retarding fungous growth. These problems are of primary importance. Until the decay and stain defects which are found in varying amounts in all the timbers are known in detail, and the progress and processes of their development and the conditions under which they thrive are understood, there is no foundation upon which to base studies of the utilization of diseased material or investigations of effective methods of disease prevention or control.

In Canada, where virgin stands of overmature timber are still being cut and where the second-growth forests are for the most part unregulated, a large supply of diseased material will for many years appear on the market. It is probable that much of this could be used with profit, and with a sense of security, if the nature of the material were clearly understood. A case in point, in which a knowledge of chemical changes would assist in conservation, is the use of diseased spruce in the manufacture of chemical pulp. Spruce is unfortunately subject to attack by several fungi, each of which decomposes the wood in its own way. A knowledge of the cellulose content of spruce decayed by the several organisms would permit of the selection of rotted wood with a high percentage of cellulose and the rejection of that in which the cellulose had been destroyed. This might effect the conservation of large quantities of infected spruce. Studies have already been made along these lines, but much still remains to be investigated.

The problems of *industrial research* fall into two groups, namely, (1) utilization investigations, and (2) special problems peculiar to individual industries.

Experiments in the utilization of diseased material must be made in an attempt to settle the question of the suitability of such wood for service. An example of such studies is to be found in the case of red-stained jack pine. The red-stain disease is contracted in the forest; but it has been shown that it does not affect the mechanical properties of the wood until it has reached an advanced stage. If the reactions of the disease to service conditions were known, it would be possible to accept or reject with assurance much material, the profitable use of which is now questionable. Such information can be obtained only by service tests.

As examples of the second group of industrial problems (i.e., problems peculiar to individual industries or situations) may be cited the moulding of pulp, the accumulation of slime in pulp and paper mills, and decay in buildings or exposed structural timbers.

It is the aim of the laboratories to make the third category of the work of the division, viz., *technical service*, as efficient as posible. To that end the library is well supplied with standard works and current periodicals dealing with pathological investigations. These periodicals are followed; all papers dealing with timber pathology are carefully scrutinized; and references pertinent to the work are systematically filed so that they are readily accessible. The work of other laboratories is also carefully followed. All available information is furnished on request; and investigations may be instituted if questions submitted have reference to points not answered in the literature.

IV. *Investigations Completed or in Progress*

From 1915 until the summer of 1924 the work of the division included two major projects, namely, (A) Decay of timbers in buildings, and (B) Decay of wood and wood products.

(A) *Decay of Timbers in Buildings*

The study consisted of a survey of mill and factory buildings for the purpose of noting the species of timber in use, the types of construction employed, together with the prevailing moisture and temperature conditions, and the durability of the timbers in the situations encountered. Two hundred and thirty-four plants were visited; and conditions were noted in buildings devoted to spinning, weaving, dyeing, bleaching, and finishing of textiles, the canning of food, pulp and paper making, and tanning. Upwards of 300 inspections were made of roofs, floors, basements, and supporting timbers. During the course of the investigation specimens were collected and photographs taken to illustrate the conditions encountered.

Roofs.—Two hundred and fifty-four roofs were inspected. These were made of white, red, and southern pine, spruce, hemlock, Douglas fir, and tamarack. They were constructed of 2-inch, 3-inch, 4-inch, or 5-inch planks, 2-inch by 3-inch and 2-inch by 5-inch planks on edge, single planks sheathed without an air-space, planks sheathed to form an air-space of one or more inches, or of three layers of wood enclosing two air-spaces. The material used was in the form of straight-edged boards, tongued-and-grooved lumber, or splined planks. Throughout the wide range of materials examined and the varied forms of construction encountered in the buildings visited, no type of roof observed offered any appreciable superiority as regards durability. All decayed with such rapidity that renewals were necessary after a service of eight or nine years.

It is to be noted that in the mills and factories inspected the processes of manufacture demand, or give rise to, high humidity of the air. Moisture is a

controlling factor in fungus development; and it was found that in cold weather condensation of moisture on the roof-timbers was the common condition. The cold outer air reduced the temperature of the roof-decks below that of the air inside the buildings. Warm, moisture-laden air rising in the interior of the buildings was cooled below its dew-point, and deposited its moisture on the under surfaces of the roofs. This moisture was soon absorbed by the wood, which was thus well conditioned for the development of decay-producing organisms. Air-spaces in the roof proved an aid rather than a hindrance to decay, since moisture collected in these spaces and provided an added source of supply.

Careful consideration pointed to the following as controlling factors in roof preservation:—

(*a*) Conservation of heat in the timbers of the under layer of the roof by construction of a roof-deck of sufficient thickness to prevent rapid radiation;

(*b*) Insulation of the outer roofing timbers from the moist air of the interior by use of a layer of water-proofing material;

(*c*) Use of rot-resistant wood;

(*d*) Uniform heating of the roof;

(*e*) Removal of moisture by ventilation where the processes of manufacture permit.

It was found that all these factors could be successfully controlled. For the roof-deck proper red cedar or redwood were recommended as rot-resistant woods. By covering one of these with three plies of tarred felt, mopped solidly together with hot pitch, the passage of moist air to the cold upper surface of the roof could be barred. It was recommended that two or more inches of creosoted wood be then placed above, as a heat insulator to control the loss of heat from the inner layers, and that the outer surface be finished with weather-resistant covering as desired. Suggestions were also made for the uniform distribution of heat by the proper spacing of heat outlets or radiating surfaces, and for the control of moisture by ventilating systems suitable to the buildings under consideration.

(2) *Floors, Basements, etc.*—Upwards of fifty examinations were made of floors, basements, or supporting timbers. Moisture deposition, due to unequal heating and inadequate ventilation, was found to be in all cases the controlling factor in the initiation and development of decay. For example, in one basement examined, steam pipes had been installed on one side, but were insufficient to maintain the air of the entire room above dew-point. Consequently moisture condensed at points distant from the source of heat, and favourable conditions for decay were thus provided. Condensation was noted around drains and ventilators, and in all such cases these points proved to be centres of decay. Uniform heating and proper ventilation were, therefore, recommended as methods of control. Where adequate moisture control was not possible, the use of wood treated with a suitable preservative was advocated.

(B) *Decay of Wood and Wood Products*

Under this project two problems were considered: (1) Moulding and decay of pulp; (2) Water storage of groundwood pulp.

(1) *Moulding and Decay of Pulp.*—Stored pulp of many kinds—sulphite (bleached and unbleached), sulphate, soda, and groundwood—was examined, and samples secured for laboratory study. It was found that all types were subject to attack by moulds. Wherever sufficient moisture was present, mould-

ing and decay were inevitable. No controlled experiments were carried out; but suggestions based on the conditions provocative of the growth of decay-producing organisms were made for possible improvements in storage conditions. Treatment with sodium fluoride or other suitable antiseptic, storage in an atmosphere of carbon dioxide or nitrogen, cold storage, or reduction of moisture were recommended. The application of any one of these remedial measures would remove an essential requirement of fungous growth; but tests would be needed to determine the effect of each upon the pulp, and the feasibility of commercial application.

(2) *Water Storage of Groundwood Pulp.*—Groundwood pulp, which is composed of wood finely divided by the mechanical action of grinding on large stones, was stored in the form of slush, laps, and pressed sheets at the laboratories in galvanized iron tanks. The tanks were supplied with water, which was kept continuously flowing or changed weekly or daily. The material was stored thus for seventeen months, after which tests for freeness, bursting strength, and tensile strength were made and compared with similar tests on freshly made stock. To serve as checks on the pulp in water storage, some of the pulp was left exposed to the air of the room in which the tanks were installed, and some was placed in cold storage at 35°F.

The tests showed that in all cases there was slight deterioration after this prolonged storage in water. Running water proved to be a better storage medium than water changed daily or weekly. The pulp left exposed to the air was so far disintegrated at the conclusion of the experiment that it was felt that tests of it were unnecessary. Water storage was thus found superior to air storage for groundwood.

Pulp held in cold storage showed little deterioration.

During 1924 and 1925 there was a break in the continuity of the work of the division. In the latter year, however, pathological investigations were resumed; and during the intervening period three projects and some minor investigations have been undertaken. The major studies in progress are the following: Reference collection of pathological material (3); Slime in sulphite pulp mills, with special reference to methods of prevention (4); Red stain in jack pine: its development in creosoted and untreated railway ties under service conditions (5). During the last year the work has been interrupted owing to the removal of the laboratories from Montreal to Ottawa, and during that period only the third of these problems has received any considerable attention.

(3) *Reference Collection of Pathological Material.*—Specific diagnosis of timber diseases depends upon a detailed knowledge of the characteristics and habits of the many organisms which induce decay. The decay-producing organisms are fungus plants, which consist of a vegetative portion called the mycelium, and fruiting bodies, or sporophores. The mycelium develops in the wood tissues in the form of branching threads of microscopic size, which ramify through the wood, and absorb and assimilate the foods there found. Having penetrated the wood in all directions, the fungus plant is sufficiently well nourished in time to produce its fruits. These are the toadstools, brackets, encrusting sheets, etc., which appear on the surface of the wood and are well known to all who are engaged in the merchandising of wood. Fulfilling their purpose, these fruiting bodies spread abroad fine, dust-like clouds of spores, which are so light and yet so resistant that they provide for a wide dissemination of the fungus. Each spore, microscopic in size though it is, carries in it the possibility of further timber infection, for, given favourable conditions of germination, it is capable of developing into a new plant which has the power to infect the wood on which it develops.

Fungi are classified according to the characteristics displayed by their fruiting bodies. Many fungi destroy wood, and each fungus produces a more or less characteristic type of decay. Early studies in timber pathology based identification of the causal organisms of individual cases of disease upon the sporophores found in proximity to the decay and the characteristics, both macroscopic and microscopic, displayed by the wood attacked. It has recently been found that the mycelium, or vegetative portion of the fungus, also presents characteristics which assist in identification. The mycelium may be obtained in pure culture by taking a piece of decayed wood in which it is growing or a piece of the tissue of a fruiting body and placing it under aseptic conditions in a suitable nutrient jelly. The branching threads grow out and form a tangled mat on the surface of the jelly. It has recently been noted that each fungus produces a more or less constant type of mat when grown under standardized conditions.

It is now recognized that the presence of a sporophore in proximity to decay is no guarantee that it is a production of the mycelium of the primary or principal agent of destruction, since secondary organisms are all too abundant and active in following up decay already initiated and in continuing the disintegration of woody tissues. For the same reason it is evident that the isolation of a known mycelium from a piece of decayed wood does not determine conclusively the identity of the organism responsible for destruction. Further, as the study of wood decay progresses, the suspicion arises that more than one fungus may be responsible for some types of rot. It must, therefore, be evident that a knowledge of all three aids to identification, viz., (A) sporophore characteristics, (B) method of attack on wood, and (C) mycelial peculiarities, should be at hand, in order to determine rightly the nature of any disease. Up to the present all too few types of decay have received adequate treatment in published records. As a result much uncertainty exists when specific diagnosis is demanded.

In order to facilitate the accurate determination of the agents inducing disease, and thereby furnish a basis for recommendation concerning utilization and preservation of partially decayed wood, there is being built up at these laboratories a collection of pathological material, which includes:—

(*a*) Sporophores of wood-destroying fungi,
(*b*) Pure cultures of the mycelium of wood-decaying fungi,
(*c*) Blocks of wood decayed in pure culture by known fungi,
(*d*) Blocks of naturally decayed wood from which known fungi have been isolated, and
(*e*) Microscopic sections of naturally infected wood and of wood decayed in pure culture.

The collection of sporophores and rotted wood contains at present 554 specimens, which are carefully boxed and systematically arranged. There is on hand a stock of 67 pure cultures of known fungi from sporophores or rotted wood, and 47 of unknown identity which have been isolated from decayed wood and retained, in the hope that when the stock series provides a more complete set of sporophore cultures, their identity may be established.

(4) *Slime in Sulphite-pulp Mills, with Special Reference to Methods of Prevention.*—Even a casual examination of the pipes, head-boxes, and storage tanks throughout a pulp-mill reveals a rather general distribution of a thick, slimy substance adhering to the walls. This is often dark in colour, especially in the layers adjacent to the substratum. If a portion of a wall be cleaned off and the spot be examined a week later, in all probability it will be found that

the slimy layer has been renewed. Continued growth and constant regeneration produce this material in such abundance that portions of the thickening layer are constantly being broken off and carried along in the pulp stream, until passed through to the dried pulp, where they cause dark, unsightly spots which necessitate a degrading of the pulp and a consequent loss in value to the mill concerned.

Realization of the losses sustained by the industry through the development of this slime resulted in a request to the Forest Products Laboratories for assistance in making an investigation of the trouble; and, after due consideration, studies were instituted. The study aims to elucidate the following points regarding slime:—

(*a*) Its distribution in pulp- and paper-mills,
(*b*) Its composition,
(*c*) Its origin,
(*d*) Conditions conducive to its growth,
(*e*) Means of combating its development.

Five mills have been visited and conditions examined. Samples of slime, raw water, pulp, and infected pulpwood have been collected and shipped to the laboratories for study.

The mill slimes consist for the most part of filamentous fungi of the mould type, although bacteria and yeasts form a dominant element in some slime samples and have been isolated from practically all the material collected. Wood-destroying fungi were isolated from some pulpwood sticks, but have not been obtained from materials in the mill.

Chemicals and high temperatures used in the production of chemical pulp assure sterilization of the wood entering into their manufacture; heat generated in grinding the wood has also been found to exert a very appreciable sterilizing action on ground-wood. Infection of the pulp is found to originate in raw water introduced to wash or dilute the pulp, and in contaminated material carried into the pulp stream by air currents. Much of the water used to dilute the stock in the process of manufacture drains back into the mill system as the stock passes over the pulp or paper machines, and is re-circulated with the succeeding run of stock. This water causes wide-spread dissemination of slime-forming organisms and assures their dispersal through successive lots of pulp.

It has been found that some of the dominant slime-producing fungi are able to tolerate the varied environmental conditions found in groundwood-pulp, sulphite-pulp, and paper-mill systems. These include considerable variation in food supply, temperature, acidity, and substratum of attachment.

At one plant visited experiments were said to have indicated that the application of copper sulphate in the proportion of 1·7 pounds per 200,000 gallons of water had a beneficial effect on slime control; but the abandonment of this treatment implies that the benefits were temporary; and cultural tests show that copper sulphate, sodium fluoride, and zinc chloride do not inhibit the growth of slime fungi tested, even in concentration of 0·2 per cent in malt agar.

No satisfactory treatment has yet been worked out to combat the trouble. Slime might be removed by mechanical action, or killed by heat or the application of toxic substances. The last procedure seemed the most feasible line of attack and the above-mentioned poisons were tested with the results recorded. The problem demands further study before recommendations for treatment can be made.

5. *Red Stain in Jack Pine: its development in creosoted and untreated railway ties under service conditions.*—Jack pine timber is excellently well adapted for railway-tie purposes. It grows extensively in Canada, is relatively strong

mechanically, can be readily impregnated with creosote oil, may be seasoned to " treatable " condition in a few months, and is not in great demand for other purposes. The yearly consumption of jack pine ties in Canada is in the neighbourhood of 3,500,000 ties. In addition to the capital expended for green ties, the railway companies have to consider the cost of treatment and of labour involved in placing the ties in track. This more than doubles the original cost of the ties and involves the employment of capital of no inconsiderable amount.

Unfortunately, the susceptibility of jack pine to red stain places under suspicion a large percentage of the timber cut. The railway companies realize that this disease, present in various stages in a very considerable number of the ties which they are accepting, may seriously impair the lasting qualities of these ties when placed in the track. Knowledge of the action of the disease under service conditions is, therefore, sought; and a somewhat extensive experiment has been undertaken in an endeavour to answer questions regarding the disease which are causing grave concern to both the producers and users of jack pine timber.

In the summer of 1926 five hundred and fifty green jack pine ties showing red stain in various stages were selected and tested for the presence of red-staining fungi. In 1927, after seasoning for a year, they were re-tested. This year they will be creosoted, re-tested, and placed in the track. Periodically, groups of ties will be taken up and analysed. In this way the progress of the disease will be followed, and it is hoped that information will be obtained which will definitely establish the reactions of the disease to service conditions.

Minor Investigations.—The chief of the minor investigations which have been instituted are tests on the toxicity of substances used or proposed for use as wood-preservatives, and the decay of white cedar telephone poles. Studies on these problems are still in progress.

Work of the Vancouver Laboratory.—Pathological studies were initiated at the Vancouver Laboratory in 1925, and during the intervening period two major pieces of work have been undertaken, namely, the preparation of a bulletin on natural defects in British Columbia softwoods (6), and a study of the effect of storage in fresh water on the properties of black cottonwood (7).

6. *Bulletin on Natural Defects in British Columbia Softwoods.*—Owing to the large number of inquiries regarding natural defects in British Columbia softwoods which have been submitted to the laboratories by men engaged in the lumber industry, it was decided that a bulletin dealing with this subject would be of great service to graders, inspectors and others interested in the merchandising of this class of timber. For the last three years, therefore, much time has been devoted to assembling information on the numerous natural defects which are encountered. It is intended that this shall be embodied in bulletin form and published at an early date.

Particular attention has been given to the discolorations caused by wood-destroying fungi and to sap stains; and it is proposed to include a number of coloured plates in the publication in order to render as vivid as possible the visualization of the defects described.

7. *A Study of the Effect of Storage in Fresh Water on the Properties of Black Cottonwood.*—Black cottonwood is used in the production of plywood, which is employed extensively in the manufacture of boxes, fuselage and other parts of aeroplanes, and interior panelling. Manufacturers have reported that if the cottonwood logs are subjected to prolonged storage in water, it is necessary, on account of glueing failures, to discard or degrade a much greater percentage of material than if green logs are used in plywood production. It is

also stated that the heat value of the cottonwood cores from water-stored material which are used for firing the boilers is appreciably less than that of cores from green stock.

In order to determine whether water storage is in reality responsible for this change and deterioration, a systematic investigation has been planned to establish the changes which occur in black cottonwood during a year's storage in fresh water. Two bolts of this, five feet in length, and of a quality typical of plywood material, were obtained. On receipt of these, strength tests and cultural analyses of a section of each bolt were made, and the remainder of the wood was stored in a tank of water. Tests similar to those made on the fresh material are being made at intervals of three months on sections cut from the stored bolts. After the final tests at the end of the year it is hoped that it will be possible to make a definite statement regarding the progressive changes in the wood resulting from water storage.

V. Problems Awaiting Attention

A comparison of the accomplished work of the laboratories with the scope of timber pathology as set forth in an earlier section of this paper will show that the division is confronted with no dearth of problems calling for investigation. In the matter of rots which have been contracted in the forest there is an almost untouched field for study. Some attention has been given to defects of balsam fir and spruce in the east; considerable work has been done on jack pine; and without doubt many of the defects in British Columbia timbers will prove similar to those reported for the timbers of the western states of the United States; but even in these studies only a beginning has been made.

In regard to felled timbers the question of the moisture requirements of decay-producing organisms is the most important problem demanding consideration. We know that moisture is required for fungous growth, and that specific differences are displayed by fungi in this respect; but the exact limits of the moisture tolerance of different organisms is not known, and is of importance both in storage and shipment of timber, and in building construction.

Questions concerning sapstain, in regard to etiology, development, and control, offer opportunities for extensive studies; and the relative durability of different timbers is the source of frequent inquiries, which cannot be adequately answered from the information available from our present store of knowledge.

The aim of the laboratories is to assist in building up a store of accurate information regarding fungous defects in Canadian timbers, the susceptibility to disease of various timbers, conditions provocative of infection and decay, and assured methods of prevention or control. To ensure the best utilization of our timber resources the susceptibility of wood to disease must be borne in mind, and a knowledge of the possibilities and limitations of wood as structural material sought. It is, therefore, the aim of the laboratories to secure and supply to the wood-using industries as much information as possible which will tend to render the utilization of timber as universal and reliable as the characteristics of the material permit.

VI. List of Publications

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